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ON THE VALUE OF THE EVIDENCE FURNISHED BY VERTEBRATE FOSSILS OF AGE OF CERTAIN SO-CALLED PERMIAN BEDS IN AMERICA

E. C. CASE

In 1876–77 Cope referred certain beds in Illinois and Texas, bearing vertebrate fossils, to the Permian Age. This has stood almost without challenge until very recently and has had a very considerable effect on the literature of the Permian. The recent discovery by Mr. Raymond of reptilian remains, of the same character as those referred to the Permian from Illinois and Texas, in the Coal Measures of Pennsylvania[1] renders it desirable to re-examine the evidence upon which the position of the beds was determined. The conflicting evidence of invertebrates and plants will not be discussed as they will be considered in the accompanying papers.

In re-examining the evidence for the age of these beds it seems necessary to consider two points:

1. The morphological comparison of the North American forms with those of known Permian Age from Europe and other continents.
2. The possibility of the introduction of reptilian life at an age earlier than the Permian.

In discussing the first question it will be best to pass in review the evidence upon which Cope based his determination of the Permian Age of the beds. The scope of the article will not permit discussion of the details of comparative anatomy and so the arguments will be based on conclusions which have been reached by various anatomists, leaving the details to another time and place should a discussion arise.

Cope's evidence: The first mention of vertebrate remains from Illinois was in 1875:[2]

> A remarkable peculiarity of the vertebrae of the series is the longitudinal perforation axial of the centrum. They present the character observed in *Arche-*

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[1] *Science*, Vol. XXVI, December 13, 1907.

[2] *Proc. Acad. Nat. Sci. Phil.*, 1875, p. 440.

gosaurus and other stegocephalous Batrachia, but which also exists, according to Gunther, in the living Rhynchocephalous lizard, the *Sphenodon* of New Zealand. The bones of the limbs and the scapular arches are decidedly reptilian, and so unlike those of any Batrachia with which we are yet acquainted, that I am disposed to refer them to the former class. And as there are several points in which the fossils resemble the order *Rhynchocephalia*, I refer them provisionally to that neighborhood. They constitute the first definite indication of animals of that type in the western hemisphere.

Associated with these saurians were found the teeth of two species of fishes which are important in evidence of the position of the beds in which they occur. One of these is a new species of *Ceratodus*, Ag., and the other a *Diplodus*. The former genus is characteristic of the Triassic period in Europe, one species having been found in the Oolite. It still lives in North Australia. In both of these respects the Rhynchocephalian lizards present a remarkable coincidence. They also belong to the horizon of the Trias in Europe; and the only living species is found in New Zealand. Thus it would seem that a fragment of this fauna, so ancient in the northern hemisphere, and so remarkably preserved in the southern, has been brought to light in Illinois. It must be added in reference to the geological age of the fossils, that the genus *Diplodus* has not yet been discovered above the Carboniferous, and that one genus of the *Rhynchocephalia* belongs to the Permian of Germany. We therefore wait further material before venturing to decide whether they belong to Triassic or Permian time.

In May, 1877, he read a paper before the American Philosophical Society in which he reaffirmed the probable Permian character of the beds:[1]

After an examination of the first fossils from this fauna which came under my observation, I left the question undecided as to whether its characters pointed to the Triassic or Permian Age. The Reptilia and a *Ceratodus* pointed to the former; the *Diplodus* pointed even to the Coal Measures. The additional evidence adduced in this paper adds weight to both sides of the question. Of the fishes added, *Ctenodus* is a genus of the Coal Measures, and while *Strigilina* is new, its affinities are to the Petalodont genera of that formation. On the other hand the reptilian character of *Clepsydrops* is established, and the number of its species is increased. Now the Coal Measures have nowhere disclosed reptilian remains, so far as we have determinations of a reliable character; Batrachia were the only type of air-breathing vertebrata known to that epoch. The present fauna must then be placed above the Coal Measures, and the horizon will correspond more nearly with the Permian than with any other embraced in the system.

From its most characteristic fossil, the bed might be called the *Clepsydrops* shale. Its position according to Dr. Winslow is near the top of the Coal Measures, and is marked No. 15, in Professor F. H. Bradley's section of the Coal

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[1] *Am. Phil. Soc. Proc.*, 1877, Vol. XVII, p. 64.

Measures of Vermillion Co., in the *Report* of the Geological Survey of Illinois by A. H. Worthen, Vol. IV, p. 245. It is about 111 feet, averaging different localities, from the summit of the series, and 2,099½ feet from the base. Two insignificant beds of corals [misprint for *coal*] occur above and the following genera of invertebrate fossils: *Productus*, *Spirifer*, *Athyris*, *Terebratula*, *Hemipronites*, *Retzia*, *Zeacrinus*, *Cyathaxonia*, *Discinia*, *Lingula*, *Cardiomorpha*, *Orthoceras*, and *Nautilus*. Several of these genera are found in the Zechstein, while others belong to the Coal Measures and below them.

In another paper of the same year he says:[1]

Twenty species have now been obtained from the *Clepsydrops* shale, the exact geological position of which remains to be accurately determined. Dr. Winslow informed me that they are the bed No. 15 of Professor Bradley's section of the Carboniferous rocks of Vermillion Co., Illinois. This places them at the summit of the Carboniferous series, below two thin beds of coal. I am now informed that this portion of Professor Bradley's report is not correct, and that No. 15 occupies a much higher position than he assigns to it. It lies unconformably above the meron sandstone of Mr. Collett, which deposit is above the Coal Measures and unconformable to them. The stratigraphic evidence is thus confirmatory of that derived from paleontology, that the *Clepsydrops* shale occupies a position in the scale above the Coal Measures.

A page or two farther on in the same article he correlates the Texas and Illinois horizons (p. 193):

The discovery of a species of the genus *Clepsydrops* in Texas, in a formation hitherto regarded as Triassic, adds weight to the view above expressed, that the *Clepsydrops* shales of Illinois belong either to the Triassic or Permian formations.

In 1878 he definitely asserted the Permian Age of the beds:[2]

The Texan genera of this group (Pelycosauria), so far as yet known, are about equally related to the Ural and South African types. The age of the former deposit is the Permian, which includes, according to Murchison, the Todtliegende and the Zechstein of Thuringia. The age of the South African beds is uncertain but is suspected by some authors to be Triassic, and by Owen to be Paleozoic. In discussing the *Clepsydrops* shales of Illinois, which had been referred to the Coal Measures by previous investigators, I left the question open as to whether they should be referred to the Triassic or the Permian formations. The evidence now adduced is sufficient to assign the formation, as represented in Illinois and Texas, to the Permian. Besides the saurian genera mentioned above, the existence of the icthyic genera *Janassa*, *Ctenodus*, and *Diplodus*, in both localities, renders this course necessary.

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[1] *Am. Phil. Soc. Proc.*, 1877, Vol. XVII, p. 182.

[2] *Ibid.*, p. 350.

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1. The horizon of the *Clepsydrops* shales of Illinois and the corresponding beds in Texas is Permian.

Finally in 1879, in a comparison of the vertebrate horizons of Europe and America,[1] he gave the following table:

West Europe		North America
Thuringian	Permian	*Clepsydrops* shale
Lodevian		*Eryops* beds

And says:

> The Permian vertebrate fauna which I discovered in Illinois and Texas exhibit close parallels, but not yet generic identity, in the two continents. Thus the American *Clepsydrops* and *Dimetrodon* are near to the *Deuterosaurus* of the Perm of Russia, and the *Lycosaurus* of the mountains of South Africa. The Texan genus *Pariotichus* may, with further information, prove to be identical with the *Procolophon* Ow. from the Tafelberg. Humeri of the type discovered by Kutorga in Russia and by Owen in South Africa, are found in North America, and the same remarkable type has recently been discovered by Gaudry in France. The peculiar type of Labyrinthodont vertebae described by me under the genus *Rhachitomus* from Texas has been discovered by Gaudry in France. The present indications are that close similarity between the faunae of this period in Europe and America will be discovered. Nevertheless up to the present time no representatives of the striking American forms, *Diadectes*, *Bolosaurus*, *Empedocles*, and *Cricotus*, have yet been found in any other continent (p. 34).
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> The oldest of these I have called the *Eryops* beds, from the most abundant genus of Labyrinthodonts which is found in it. They contain also abundance of other vertebrata, none of which are higher than the reptilia (order *Theromorpha*), with plants, mollusks, etc. They consist of sandstones, alternating with beds of red clay and coarse conglomerate and sphaerosiderite, etc. They are chiefly distributed in Northern Texas and Southern Indian Territory.
>
> The *Clepsydrops* shale named by me in 1865 [misprint for 1875] forms a thin stratum, in southeast Illinois and southwest Indiana, consisting of black and rarely reddish carbonaceous shales and clays. These appear in some places to lie conformably upon the Coal Measures, to which they have been referred by previous geologists, but Collett, Gibson, and others have shown that it is unconformable over considerable areas. It does not belong to the Coal Measures (p. 52).

After this paper Cope consistently referred to the beds as Permian.

Reviewing the evidence cited above we find that the beds were so referred on—

1. The presence of reptiles.

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[1] *Bull. Geol. and Geog. Survey of the Terrs.*, 1878–79, pp. 33–54.

2. The similarity of the *Poliosauridae*[1] and the *Clepsydropidae* to the reptiles from the known Permian of Europe and Africa.

3. The similarity of certain amphibians, especially *Eryops* and *Trimerorhachis*, to known Permian forms.

4. The presence of *Janassa*, *Ceratodus*, *Ctenodus*, *Diplodus*, and *Strigilina*.

5. He suggests the similarity of *Pariotichus* of Texas and *Procolophon* of South Africa.

These points will be discussed *seriatim*.

1. The argument from the presence of reptiles may be rejected at once as this is part of the question on trial. In a later paper (*Proc. Am. Phil. Soc.*, 1897, p. 88) Cope identifies one of his Permian reptiles from Illinois, *Isodectes*, in a form that he previously considered as an amphibian, *Tuditanus* from the Coal Measures of Linton, Ohio. So that he himself recognized the possibility of reptiles occurring below the Permian. The validity of this identification may be questioned, however.

2. The morphological similarity between the reptiles from the Illinois and Texas beds and reptiles from known Permian beds of Europe and Africa.

Cope depends on three points in particular.

a) The resemblance between *Clepsydrops* and *Lycosaurus* from the Permian of South Africa. This, with all other comparisons between the reptiles of the two continents (except perhaps the *Cotylosauria*) may be dismissed, as the forms have been shown to be so radically different (Diapsidan in North America and Synapsidan in South Africa) as to preclude any possibility of their use in indicating the contemporaneity of the beds.

b) The resemblance of *Clepsydrops* to *Deuterosaurus* of Russia. The skulls of *Deuterosaurus* and *Rhopalodon* have repeatedly been described, but their condition is such that no definite conclusions can be drawn, but the weight of evidence seems to be that they are nearer to the South African forms than to the North American.

c) The notochordal condition of the vertebrae, and the resemblance of certain humeri to humeri from the Permian of France. The first character cannot be considered as distinctive of the Permian;

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[1] Case, *Publication 55*, Carnegie Institution, Washington.

it is characteristic of the most primitive type of reptiles and persists even to the present (*Sphenodon*).

The humerus mentioned by Cope was that of an amphibian or one of the *Diadectidae* and the French form was probably *Euchirosaurus*.

3. With regard to the amphibians the evidence is scarcely better. Cope emphasizes the rhachitomous character of the vertebrae and compares the condition of *Eryops* and *Trimerorhachis* with similar rhachitomous forms from the French Permian, the genus is not mentioned but it is evident that he had *Euchirosaurus* in mind. This character of the vertebrae comes nearer to being a determinant character than anything mentioned by Cope, but it is open to question because the same form of vertebrae occurs in the Carboniferous amphibian, *Dendrerpeton*.

4. The fishes mentioned by Cope have the distribution shown below:

Sagenodus—Carboniferous and Lower Permian.
Janassa—Carboniferous to Triassic.
Strigilina—A petalodont selachian of Carboniferous affinities.
Diplodus (*Orthocanthus*)—Carboniferous and Permian.

Evidently the fishes are of little more value than the amphibians and the reptiles.

5. The *Cotylosauria* common to North America and South Africa. The similarity of *Pariotichus* and *Procolophon* was suggested by Cope; this has been shown to be impossible, but Williston has very recently (*Journal of Geology*, Vol. XVI, No. 2, 1908, p. 148) attempted to show that *Labidosaurus*, a form very closely related to *Pariotichus*, is also very closely related to *Procolophon*.

However, even if this should be accepted, the presence of two distinct genera of this extremely primitive order could not prove the contemporaneity of two beds in such distant regions.

The evidence adduced by Cope is not sufficient to prove the Permian Age of the Illinois and Texas beds as against a possible Carboniferous Age.

It now remains to examine the evidence discovered since 1877. Undoubtedly Cope regarded much of this as directly confirmatory of his ideas.

1. There have repeatedly been suggestions that reptiles occur in beds below the Permian. Two examples suffice:

As cited above, Cope identified a reptile in the beds of Linton, Ohio. Following is a quotation from a letter written to the author by the late Dr. Baur, dated June 20, 1897:

> I have found out that *Hylonomus* Dawson, and *Dendrerpeton* Owen, and *Petrobates* Credner, are reptiles and not Stegocephalians. All these forms are Carboniferous with the exception of *Hylonomous,* which is also found in the Permian, and *Petrobates,* which belongs to the Permian alone. The vertebrae are elongate and biconcave, chevrons intercentral, ribs two-headed, long, slender, and bent. Teeth smooth, with large pulpa. Two sacral vertebrae, the second with small sacral rib. No cleithrum. Interclavicle T-shaped, clavicle slender. Ribs of caudal vertebrae bent backward. These forms are directly ancestral to the *Paleohateriidae. Microsauria* Dawson is the proper name for them. This fact, of course, makes the *Microsauria* the oldest reptiles, from which the *Paleohateriidae* and the *Rhyncocephalia* are directly developed.

The position taken in this letter was defended in the *Anatomischer Anzeiger*, Bd. IV, pp. 146–51.

2. The difficulty in distinguishing between the primitive reptilia and the amphibia has steadily increased by the discovery of intermediate forms, so that it is practically impossible to draw a line between the two today. The presence of a distinct parasphenoid bone distinguishes the amphibia, and in the Texas beds the presence of an entepicondylar foramen in the humerus distinguishes the reptiles, but this cannot, perhaps, be depended on as a general character of value.

We now proceed to the consideration of smaller groups.

Poliosauridae.—These may be related to the *Proterosauridae* rather more closely than to the *Pelycosauria* with which they have been described. *Proterosaurus* and *Paleohatteria* are typical members of the *Proterosauria* from the Permian.

Clepsydropidae.—No forms of this family occur in the Permian of Europe. *Ctenosaurus,* an aberrant, related form, is from the Bunter Sandstein and *Anomosaurus,* a doubtfully related form, is from the Muschelkalk.

Naosauridae.—A single species of this genus has been found in the Permian of Bohemia.

Pariotichidae.—No forms are known outside of the Texas beds.

Pareiasauridae.—Very doubtfully present in North America.

Among the amphibians—

Eryops.—Closely related in the rhachitomous character of the vertebrae to *Actinodon* and *Euchirosaurus* from the Permian of France.

Trimerorhachis.—No close relative of this form is known except in the character of the vertebrae.

Cricotus.—This resembles *Archegosaurus* in the embolomerous character of the vertebrae which occurs in the caudal series of *Archegosaurus* and throughout the column in *Cricotus.*

Dissorhophus and *Diplocaulus.*—Have no equivalents.

Crossotelos, Case.—This shows the characters of fringed dorsal and haemal spines in the caudal series such as occurs in *Urycordylus* and *Oesteocephalus* both from the Carboniferous.

The numerous smaller amphibians from Texas are so imperfectly known that it is impossible to make profitable comparisons with other forms.

Among the fishes—*Janassa* (*Thoracodus*), *Orthacanthus, Ctenodus, Ptyonodus* (*Sagenodus*), have been discussed above.

Didymodus.—Known from the Carboniferous of Europe.

Gnathorhiza.—Known from Texas only.

Sagenodus pertenuis, Eastman.—Known from the Permian of Russia (*fide* Broili).

Ectosteorhachis.—Known from Texas only.

We may now reject all the evidence furnished by the fishes except *Sagenodus pertenuis,* because they occur both in the Carboniferous and Permian, or because they do not occur outside of North America.

We may reject all of the amphibians except *Eryops* and *Cricotus* for the same reason.

We may reject all of the solid-roofed forms, *Cotylosauria* (*Chelydosauria*), *Pariotichidae,* etc., because they have no close relatives known outside of North America.

We may reject the *Clepsydropidae* as the only possible European representative is Triassic.

There remains only the family *Poliosauridae,* the genus *Naosaurus,* and *Sagenodus pertenuis,* worthy of consideration. *Sagenodus* has been identified from Texas (Eastman) and from Russia (Broili). The latter locality, the banks of the Lusa, a tributary of the North Dwina, carries a fauna typical of the South African region.

As is well known, the genus *Naosaurus* occurs in the Permian of Bohemia.

The resemblance between the *Poliosauridae* and the *Proterosauridae* is in just such primitive and generalized characters as would persist from one formation to another.

The evidence for the Permian character of the beds rests then on the presence of a single genus, *Naosaurus,* common to the Permian of North America and Europe and on the community of many very primitive characters and numerous more specialized ones, which, however, reach either down into the Carboniferous below or up into the Triassic above.

CONCLUSION

1. The evidence from vertebrates is not sufficient to demonstrate the Permian Age of the beds in Illinois and Texas, they may reach down into the Carboniferous or they may extend upward into the Triassic.

2. There is no unlikelihood that reptilian life began in the Carboniferous. The evidence is rather affirmative than otherwise.

It is becoming more and more evident from the vertebrate paleontology that the Red Beds of North America and their eastern equivalents represent an enormous interval of emergence which may well have begun while Carboniferous (Pennsylvanian) forms still lingered in the waters and have continued until Triassic types were well established.